12 Oct 1978

Usable Energy Resources Expand Under the Economic Pressures of Fuel Scarcity

Raphael Shen

USABLE ENERGY RESOURCES EXPAND UNDER THE ECONOMIC PRESSURE OF FUEL SCARCITY

Raphael Shen
University of Detroit
Detroit, Michigan

Until mankind finds properties in materials that are useful and usable under given economic conditions, these materials are not resources. In the past, many of them became usable as the ones they replaced became scarce and expensive. Market induced R & D toward profit seeking and cost minimization hastens to incorporate currently unused materials into the productive processes. With the increase in oil and natural gas prices, hitherto untapped energy sources present themselves as attractive alternatives. There will be no permanent shortage of energy resources, and the current energy crisis will be a page of past history in the foreseeable future.

William Javon warned his government in 1866 of the impending coal depletion in England.(1) The U. S. Geological Survey in the late nineteenth century predicted that there was little or no chance of oil discovery in California, Kansas or Texas. The Bureau of Mines estimated in 1914 that the total future oil production in the U. S. would not exceed 5.7 billion barrels. And in 1949, the U. S. Secretary of Interior asserted that the U. S. oil supply was coming to an end.(2)

These predictions and prophecies did not materialize. The United Kingdom exported 2.7 million tons of coal in 1973,(3) and the U. S. oil reserve in 1975 was estimated at 50.1 billion barrels--the largest ever.(4) The non-fulfillment of past prophecies was primarily due to the interplay of market forces via technological advances. In response to the energy crisis of 1973, more new oil fields have been found,(5) limited increase in the consumption of alternative sources of energy--oil from tar sands, biomass and solar energy, among others--have materialized, and growth in oil and gas consumption has been curtailed. But there is serious concern whether,with fuel energy conventionally coming from non-renewable sources, the projected doubling of energy consumption every ten years can be supplied within acceptable price ranges. To address this question, this paper: (1) briefly traces the various sources of energy over time; (2) surveys world energy consumption in recent decades; (3) outlines economic reasons leading to the current energy crisis; (4) discusses the workings of pricing mechanism in the provision, allocation and consumption of energy; (5) highlights measures in search for sources of energy; and, (6) concludes with a note of realism: due to economic forces, the energy crisis will be a page of past histor in the foreseeable future.

1. SOURCES OF ENERGY OVER TIME

At the dawn of civilization, wood burning served to yield heat and to prepare foods but not to perform worl in place of labor. Coal, oil or natural gas were unknown, had no economic value and were not considered as resources. Not until a little more than two centuries ago did the usefulness, and hence the value, of coal became widely acknowledged. Propelled by the Industrial Revolution, coal's prominence was gradually established among the then more developed economies. Demand for coal increased over time because it was a more abundant and convenient form of energy than firewood. Steam engines and machine tools were designed to consume coal, and industrial societies came to be more dependent on coal supply. The prospect of increasing demand for coal, and hence firm prices, induced investments in and discoveries of more coal mines. Easier to mine, and hence lower per-unit-production-costs, field were first discovered and exploited. Thereafter, deeper, higher-sulfur and lower BTU content coal mines had to be resorted to. The cost of production, and therefore unit price, rose, leading "concerned citizens" to reach the conclusion that coal supply was less than adequate and depletion of reserves was in sight. Little were they aware that consumers' reluctance to pay high prices would reduce the growth in demand and producers

profit motivation would set searching activities in motion, not only for new coal deposits but for coal substitutes.

Fuel oil was found to be cleaner to burn, cheaper to extract, more convenient to transport and higher in per unit BTU content. Coal "lost" its prominence precisely because of its initial higher prices and feared scarcity. New engines and industrial products were then designed to consume oil instead of coal. Though natural gas is often discovered with oil fields, the supply of oil then more than met the demand for fuel energy. Little economic incentive was present to develop technology to supplement energy sources with natural gas. As oil began to flow from wellheads to consuming units, natural gas was burned off. The ability of substituting fuel energy for human and animal labor increased productivity, enhanced welfare and quickened the pace of economic development. Higher income led to greater demand for goods and services, which in turn caused steady increases in fuel energy consumption. Increased energy demand called forth increases in supply, and economic viability of natural gas made its debut. Since natural gas requires more expensive and complex storage facilities and more sophisticated distribution systems than oil, justification for expenditure on developing gas market did not exist until demand for fuel energy steadily rose.(6)

The principle of substitution--when one input becomes economically viable and performance-wise is capable of substituting in part or replacing another input in whole--explains the historical trend of decreasing prominence of coal and increasing importance or value of oil and natural gas. As oil and natural gas prices continue to rise, reflecting both artificially curtailed supplies from oil exporting nations and increasing cost of production, oil importing nations correspondingly adjust their growth in demand downward while exploring alternative sources of energy. The more rapidly oil prices should rise, the more intense will the search for substitutes be, hastening the process of eventual replacement of oil and gas by substitute energy forms. The restraints in recent years on oil price increases exercised by major oil exporting nations could well be a concealed effort to stall such a process. Nevertheless, the lustre enjoyed by oil and gas in recent memory has already begun to wane.

2. CAUSES OF ENERGY CRISIS

The recent energy crisis may be attributed to seven major causes. First, the conventional forms of energy, namely oil and gas, are easier to extract, lighter to transport and cleaner to burn than coal. In the absence of an oil embargo, industrial factors of production such as machines and other hardware are all designed to burn gas or oil rather than coal, creating a situation of extremely low price elasticity of demand for oil and gas. Total dependency of a fuel-gulping economy thus unwittingly placed itself at the mercy of oil producing/exporting nations.

Second, U. S. demand for oil rose steadily from 1950's 6.5 million to 1965's 11.3 million and 1973's 17.2 million barrels per day. To meet the projected domestic demand, the oil companies's search efforts resulted in vast oil discoveries in the recent past. The domestic oil market was glutted with surplus which drove down prices, on occasion even below cost of production.(7) Cost minimization led to investment and subsequent discovery of vast Mideast oil deposits. Mideast oil was being produced at 10¢ per barrel for years.(8) Therefore, an increasing share of U. S. domestic demand was being met by imported Arab oil. U. S. oil import rose from 1950's 13.1 to 1965's 21.8 and 1973's 35.7 percent of total consumption.(9) Increasing reliance upon imports gave OPEC nations the needed leverage.

Third, the U. S. domestic reserve for oil began to dwindle as greater reliance was placed upon cheaper imported oil. In the opinion of oil companies, the government was holding down oil prices, reducing subsidies, raising environmental standards and disallowing tax breaks. As a result, exploration expanded in foreign countries where low labor cost, absence of regulatory agencies and the advantages of tax write-offs became too attractive to resist. Domestic exploration slackened.(10) Recognizing the fact that the productive capacity of the oil industry could not expand on short notice, OPEC nations knew that they could exercise certain degrees of "monopoly power".

Fourth, unlike the United States which is the largest oil producer as well as consumer, numerous developed economies in EEC and Japan are poorly endowed with oil deposits. In 1972, 60.5 percent of Japan's total energy consumption depended on oil imports from the Mideast and North Africa, whereas it was 50.6 percent for Western Europe.(11)

Fifth, in view of their value productivity, oil and gas had long been a bargain. Consumers had been accustomed to low and steady fuel prices. Therefore, when oil prices quadrupled within a year between 1973 and

1974, consumers at large were psychologically unprepared for the shock. To add insult to injury, inflationary recession and high unemployment rates followed, further accentuating an already panicky world economy.[12] The "crisis" deepened.

Sixth, oil and gas are chief sources of income for major energy exporting nations. Unless alternative sources of revenue could be found in time, these nations would have little economic base to fall back on once their wells run dry. Thus, by raising unit price and simultaneously curtailing production, the "grace period" is prolonged while the enhanced income could be wisely placed in future revenue bearing investments.[13]

Seventh, oil and gas consumers from nations of plenty were not accustomed to conservation or recycle measures. Low fuel prices rendered wasteful practices more economical than conservation. Thus, curtailed oil export and rapid rising prices by OPEC nations caught DC consumers unprepared to cope with the situation. Hence the "crisis".

3. FUEL ENERGY CONSUMPTION OVER TIME

For the world energy consumption scenario, four significant trends may be observed.

First. Rapid Increases in Energy Demand. The world per capita energy consumption increased approximately 31 percent between the years 1925 and 1950. The increase from 1950 through 1972, however, soared to 106 percent. The significance in the rapid increase in demand does not lie so much in the nearly fourfold percentage increases for the two comparable periods as the increase in aboslute quantity demanded being concentrated mostly in developed economies. In other words, most of the demand increases took place in DCs.

Second. Substitution. Consumers substitute one form of energy for another when economic and performance advantages can be reaped by substituting the new for the conventional. As late as 1850, fossil fuels provided only 5 percent of the world's energy, whereas human and animal labor provided 94 percent.[14] Industrialization led to the increasing substitution of fossil fuel energy for human and animal labor in the production processes. And by 1970, 95.9 percent of energy expended in the U. S. was derived from fossil fuels.[15] Other than hydro and nuclear power which provide relatively constant proportion of energy supply in the U. S., the significance of coal as a chief source of fuel energy declined drastically from 1920's 78.4 percent to only 20 percent in 1970. On the other hand, in 1920 the BTUs supply by natural gas and hydro-nuclear sources were about even. But half a century later, gas-supplied BTUs was nearly 8 times that of hydro-nuclear. This is so because given the then current state of the art, the cost of exploration-extration-transportation-distribution of gas per unit of BTU supplied was much lower than harnessing hydro power or developing technology for commercialization of nuclear energy. This, however, is no longer true. Because of the energy crisis, it is reasonable to conclude that a new phase in energy consumption has emerged. Just as oil and gas increasingly substituted for coal in consumption in recent decades, the relative importance of oil and gas will similarly diminish in favor of more abundant and cheaper alternative sources of energy in the long run.

Third. Increasing Reliance on Imports. Substitution of oil and gas for coal in DCs was made feasible through trade. Since it was cost effective to use foreign oil, entrepreneurs from DCs poured both capital and technology into LDCs in search for oil and gas. As a result, foreign crude oil reserves soared beginning with the late 1940's. Until the energy crisis in 1973, oil and gas imports by DCs in general steadily grew. Thus, the U. S. energy imports in 1950, in terms of total energy consumption, were less than 10 percent. By 1972 they rose to 41.9 percent. In the long run, when market induced R & D gathers momentum due to oil and gas price increases, less expensive and more abundant resource bases promise greater degrees of energy self-sufficiency and reduced reliance on energy imports.[16]

Fourth. The Increasing Demand for Electricity. This topic is germane to the discussion of energy consumption in the future. This is so because of the possibility of future substitution of solar, geothermal or nuclear fusion energy for oil and gas. That electricity supply and demand constitute an important facet of the energy equation is due to its versatility, multi-source convertability, low cost delivery system and ease in application. Whether saw dust, coal, oil, gas, nuclear, solar or geothermal power is used in its conversion process, the end product for the electricity user remains the same. Substitutability among inputs allows producers to change one form of the primary energy source to another as determined by their relative prices and availability.[17] Between 1920 and 1950, demand for electricity in the U. S. increased nearly 30 fold[18] Conversion efficiency via technical improvement and subsequently lower per unit cost to consumers enabled

producers to meet the rapid increase in electricity demand.* Higher costs of primary sources brought about by the "oil crisis" have retarded the demand growth somewhat. But electricity demand is still expected to triple within the next two decades, and triple again in the two decades thereafter.[19] To assure future electricity supply adequacy at prices conducive to sustained economic growth, market forces may be relied upon to prod R & D so that adequate supply of primary sources is assured.

4. PRICING AND FUTURE SUPPLY-DEMAND OF ENERGY SOURCES

The cost of production, in conjunction with quantity supplied and demanded, influences the price level that energy producers may peg. When there was a rapid increase in oil demand by market economies shortly after WW II, oil prices soared due to the oil industry's inability to match demand with supply. Stable production costs and high prices mean unusual high returns on investment. The latter part of the 1950's saw returns on oil investment more than double that of mining, smelting, manufacturing and other industries abroad,[20] although oil prices had already begun to show signs of decline.[21] The established firms expanded production to capacity while new entrants into the industry flourished. Billions of dollars were invested by the industry to explore new fields and to expand production-refining-marketing facilities. World crude oil reserves leaped from 1948's 69 to 1962's 320 billion barrels.[22] Contrary to popular belief, the race for the dollar made the oil industry a highly competitive one. By the 1960's, as a result of intensive search for oil and vastly increased production capacity, oil supply exceeded the steady increases in demand. Oil prices steadily declined as did oil profit. As might be expected, growth in investment came to a standstill.[23] So did the "known reserves". This explains the historical fluctuations in production-reserve ratios. Low reserve in no way implies imminent physical depletion. But "concerned citizens" claim that conventional forms of energy are to be depleted in fifteen years if current extraction rate continues. They simply have not understood the workings of market forces and the economic disincentives of over supply.

The limit to energy resources occurs: (i) when consumers are unwilling to pay the prices which due to real energy shortages exceed their marginal value productivity; or, (ii) when the energy required in the production process of an energy fuel exceeds what is produced in its marketable form. It could occur when vast amounts of energy are needed to extract a small quantity of low grade oil lying at great depth.

Neither of these two limitations is likely to occur in the foreseeable future for the following nine reasons.

First, due to continuous technical advances, the costs of production have remained relatively stable over time. Therefore, no producer will price himself out of the market when the oil industry, in the absence of collusive activities, is sufficiently competitive.

Second, despite quadrupling of oil price in the 1973-1974 period, the reduction in the quantity of oil demanded has not decliend in any significant measure. It reflects the high price inelasticity of demand for oil on the one hand and real value of oil to consumers on the other. This latter factor is particularly obvious in the U. S. where oil price, relative to European nations and Japan, is still very much a bargain.

Third, though the current reserve-production ratio is low compared to a decade ago, it can be explained by the fact that investment in oil prospecting and exploration had been sluggish prior to the Arab oil embargo because of a lack of economic incentives. Even without taking into account the probable technological breakthroughs in energy fields between now and the end of the century, and not counting oil reserves in shale and tar sands, current known reserve can readily meet a projected fourfold increase in energy demand for the next quarter century.[24]

Fourth, as a result of the energy crisis, R & D and investment in energy fields have intensified--both for economic stability and national security, by the private as well as the public sectors. Known reserves of exploitable fuel energy will undoubtedly increase, thus discouraging price increases for any sustained period of time.

Fifth, with any significant increases in oil/gas prices, energy efficiency will increase, leading to relative stability in the price of per unit output.[25] Energy efficiency also helps to reduce energy demand on the aggregate. Lowered pressure on energy demand

*"At the turn of the century it required seven pounds of coal to produce one kilowatt hour of electricity. Now it requires less than one pound." cf. W.N. Peach, The Energy Outlook for the 1980's. Washington, D.C. : Government Printing Office, 1973, p. 17.

will then cause stabilization in supply prices.

Sixth, since the latest oil price increase in early 1977, after adjusting for inflation beginning with the same period, the real price of oil has declined by 12 percent. If anything, this phenomenon reveals the absence of a real shortage and confidence in its abundance.

Seventh, cost of oil production has remained relatively stable in recent years indicating that there are adequate oil reserve and that producers need not resort to extracting vast quantity of lower grade oil.

Eighth, oil deposits in China and Russia, if made known, can create oil "reserve glut", especially in view of current efforts underway in China to use more advanced techniques to identify and mine hitherto unexplored sites. Both Chinese and Russian oil reserves are separately estimated to be close to 45 billion tons each, or each being the equivalent of Mideast known oil reserves.(26) And,

Ninth, the vast known reserve of shale oil and Canadian tar sand in place could be exploited should prices of conventional crude oil rapidly rise. The known shale oil in the western U. S. alone, which has not been tapped for want of economic inducements, is at least twice as much as oil reserve of the entire Mideast. And oil deposits in tar sand, not counting technological advances and hence lower extraction costs, may be obtained at between $5 to $6 per barrel--less than half of imported oil price.(27)

That the topic of energy fuel depletion is brought up at all is because alarmists take "proven reserves" as an indicator of physical quantity in place. But energy resources are not termed reserves until they are first identified to exist, and secondly the identified resources are deemed extractable at competitive cost relative to alternative sources of energy. Consequently, as long as current known reserves can be expected to adequately supply foreseeable future demand at stable prices, there is no economic motivation to conduct search activities lest overly abundant known reserves depress energy prices. Thus, known energy reserve should in no way be equated with the totality of physical quantity encrusted beneath the earth.(28) Proven reserves may readily increase either through new cost reducing techniques which enables the exploration of what has hitherto been considered economically non-viable low grade sources, or increase in energy prices which would make additional exploration and extraction economically more attractive.(29)

Conservationists' concern over depletion of fuel energy does not take into account the effective forces of the market to balance supply with demand. The fact that oil recovery factors may be improved with the aid of newer technology and improved management practices implies that the "day of reckoning" may be comfortably postponed to permit the development of less conventional forms of energy. For instance, the oil recovery factor in 1945 was 26 percent. By 1965 it increased to 36 percent. That increase occurred despite declining oil prices in real money terms in the 1960s. The recovery factor increase was due purely to technical advances during that period, and technical advances are continually being made because of the competitive forces within the industry to minimize cost. Given greater economic incentives to induce better extraction practices from the same oil site, it is conceivable to further increase the recovery factor to between 50 to 60, which would mean an addition of between 56 to 96 billion barrels of oil to the U. S. oil industry alone.(30)

Estimates of oil reserve made by experts in the field may vary. But the better informed are often reluctant to estimate oil reserve beyond the end of this century precisely because of the exponential growth of human knowledge and because of increasing human ability to allign supply with demand as dictated by expected price and profit. Oil drilling has now gone as deep as 30,000 feet, producing billions of barrels of oil annually instead of two or three million per year in decades past. When it is economically attractive to drill deeper, for instance between 30,000 to 60,000 feet in a decade or two, it is probably that oil reserve may increase by 10 to 20 times.(31) It is therefore ill advised to fossilize in one's mind the currently known oil reserve statistics while maintaining the projected increases in oil demand manifold in the near future, and then claim that doomsday is upon us.

The known reserves for both oil and gas have declined from 1964 to 1973.(32) But the phenomenon only reflects the temporary absence of economic inducement for intensified search during that period. Wellhead gas deregulation, more liberal depletion allowances and higher fuel prices are only a few of the economic measures that will send investors prospecting and drilling. It is the absence of profit prospect, not physical shortage of a given resource, that retards new investment and discovery.(33)

A case may be made that it is even desirable to achieve

an orderly yet speedier depletion of conventional sources of energy. If mankind had attempted to conserve forests and firewood more than a century ago, they would probably still be considered a scarce resource today. If so, the usefulness of coal would not have been as developed, and industrialization would not have been one-tenth as rapid. If William Javon of England had his way in coal conservation, if the then known coal reserves had been superabundant and if coal prices had been stable and inexpensive, there would not have been economic incentives to exploit more desirable forms of fuel energy such as oil and gas. There would not have been the auto, air transport, recreation, and other highly productive oil-gas consuming industries which developed economies have today. Economic development would have been rolled back by decades and technologies remained primitive. The Arab oil embargo indeed could have been a blessing in disguise, which could eventually lead to abundant, nearly inexhaustible, clean and cheap energy forms such as nuclear fusion, geothermal or solar energy. Without resource shortages, known in advance, there will be little investment incentives to explore or exploit for better and more abundant resources. Or, without resource scarcity, it could mean slower economic progress and curtailed welfare improvement.

A question may be raised as to what adverse consequences an economy and a society might experience should conventional fuel resources be "depleted" and cheaper and more abundant energy forms are still unavailable for commercial marketing. The answer is that oil-gas will never be depleted and that substitutes will be developed in time to meet the challenge of a oil-gas shortage. That oil or gas will never be physically depleted may be explained thus. If ever it should occur that easier to mine, higher quality and cleaner oil-gas fields should be exhausted of their contents and that drilling deeper for lower grade oil-gas must take place, then the drilling, pumping, refining, processing and marketing cost of an equivalent unit of output will significantly increase. No consumer would be willing to demand conventional fuel energy when its cost exceeds its value product.

This logically leads to the next question, which alarmists have not undertood to ask: between the time when it is no longer economical to drill deeper for lower grade fuel energy and the time when cheap/abundant solar, nuclear or other forms of substitute energy does become commercially available, what is a developed economy to feed on? The answer is that subsitute energy forms will be developed, in time.

It was made clear earlier that conventional forms of fuel energy hitherto unidentified or unexploited for lack of economic incentives will be explored and exploited. All it requires is the "right" economic atmosphere. Because of the presence of both known and unknown deposits, a cushioning period that is sufficiently long is present for scientists to develop substitute energy forms. Energy "shortage" is neither new nor unique in a market situation. Demand for and supply of other industrial inputs have encountered similar predicaments. 1920's natural rubber and nitrate "shortages" due to cartel actions quickly led to research efforts and the resultant abundance of synthetic rubber and fixed nitrogen.(34) Firewood shortage more than a century ago developed into a coal-intensive development period.

Trendal replacement of metal products by plastics and other organic compounds, substitution of aluminum for steel, lead, copper and tin in industrial usages, increasing use of synthetic fibers in place of more expensive materials such as wood and cotton products, the development of the easier to mine lateritic nickel deposits due to hiked nickel prices are only a few of the innumerable instances in the history of economic development that speak of substitution of one input or product for another due to relative price increase/decrease. Intensive research and development effort is a function of price-profit-investment motiff.(35)

Energy resource "depletion" is no exception. Despite the vast physical presence of conventional fuel energy, intensified research efforts have already been underway to develop more abundant and cleaner energy sources. Market forces in general, and pricing mechanism in particular are at work. Unless shortage on the market is perceived, new abundance would not be sought. Without uncertainties, progress would be minimal. And, because of the prospect of depletion, mankind may move onto new and brighter horizons that promise more. Just as modern generations may find it inconceivable that our ancestors should have scrupulously conserved whale oil, a necessity then but not much of a resource, future generations will find incomprehensible that intelligent persons of the 20th century should fear for the depletion of some fossilized energy form termed oil and gas. Perhaps only future economic historians will take a slight interest in the oil conservation topic. What actions taken by researchers and policy makers to date, then, can temper the fears that persist

in the minds of some? The following section will briefly discuss this subject.

5. MEASURES TO EXPAND SOURCES OF ENERGY SUPPLY

This section may be grouped under two headings: (i) government reactions to the energy crisis; and, (ii) market response to economic signals.

First. Government Reactions to the Energy Crisis. Government responses to the energy crisis are designed to prevent social instability and economic chaos in the short run and to remove economic disincentives to energy producers for long run effects. The former include the dissemination of energy saving information, encouraging more frequent use of mass transit and car pools, reduction of highway speed, planning for oil rationing, encouraging home insulation via tax credit schemes, and moral persuassion to reduce energy consumption in general. All were designed to ease the pressure of high dependency on foreign oil. But in no way can these measures either increase energy supply for sustained economic growth or induce search for alternative sources of energy to lower future energy prices. In other words, unless government actions can evoke market responses, no long-term solutions can be found. Sustained and effective solutions to the energy crisis can only come through the interplay of market forces. As long as the marginal valuation of oil to consumers exceed prevailing prices, thermostats will remain turned to comfortable temperature, consumers will be driving instead of bus riding, cruising at 60 mph or more instead of the legal limit and paying the heating bill instead of home insulation. Where moral suassion fails, however, the dollar sign can succeed.

Second. Market Response to Economic Signals. Market response to oil price increases on the other hand has been more noticeable. Despite low domestic oil prices relative to European markets, the post embargo prices have retarded the growth in demand for oil products. Conservation measures adopted by industries and consumers is chiefly prompted by cost considerations. Since October, 1973, per unit industrial output in the U. S. on the average requires 14 percent less of energy input.(36) But this energy efficiency effort in the U. S. is still half-hearted compared to the efforts made by European and Japanese economies,(37) because energy costs in the U. S. are still being artificially kept low by the government. Allowing the free determination of energy prices according to supply and demand, energy efficiency efforts will be accelerated. Still, gas saving compact cars have become more acceptable to consumers. Taking advantage of tax incentives, home insulation is on the rise. Wood burning stoves have rediscovered a market. And, where economical, recycle and reuse of previously considered disposable wastes are in practice. These more immediate responses to oil price increases are but a few of the instances where market forces are demonstrated to be a more effective instrument in achieving policy objectives than non-market policies.

On the more positive side, steps have been taken to positively increase energy supply, either through increased exploratory activities for oil and natural gas, or actively seeking alternative sources of energy. The flurry of activities is a direct and immeidate consequence of oil price increases. And it is the oil price increase that spearheads and hastens the promise of more abundant and chaper energy supply in the long run. The remainder of the paper is given to a discussion of the impact of economic forces on the search for more abundant sources of energy for the future.

Within the arena of conventional sources of energy, deregulation of wellhead prices may be one of the most effective measures adopted by the U. S. government. It was government intervention in the energy market prior to the crisis that drove energy related capital investments abroad and correspondingly reduced domestic exploratory and productive activities. Ever since the deregulation of oil prices for oil from newly discovered fields, the oil industry has been more willing to earmark investment expenditures for both on and off shore drillings. In the U.S. along, $1.1 billion has been committed by 39 oil companies just for the right to drill for oil and natural gas off the coast of New Jersey.(38) Texas gas producers, who have been sitting on surpluses and producing at only 20 to 25 percent capacity, may not only resume full production as a result of recent Senate's passage of gas deregulation bill but will be provided with incentive to revitalize exploratory activities.(39)

The expectation of higher oil and gas prices is sufficient to set energy producers prospecting. 48,000 new oil and gas wells are expected to be completed this year--an increase of over 70 percent from 1973. And last year alone added 11.9 trillion cubic feet to the U. S. gas reserves.(40) It is reasonable to assume that should the deregulation be abolished immediately instead of in graduated phases, the

economy will be faced with energy glut instead of shortage and energy prices, via competitive forces in the market, will eventually decrease over time instead of increase. Thus, increased energy consumption may once again fuel sustained economic growth and assure social stability. While price incentive may indeed hasten the more rapid "depletion" of oil and gas deposits, as conservationists and lay persons may promptly point out, the probability is sufficiently high that reliance on oil and gas for energy sources may not last for long. For even oil and gas producers themselves have already been diversifying investment expenditures in search of more abundant substitutes and alternative sources of energy. Numerous major oil companies, expecting increasing costs for oil and gas production, have taken a keen interest in acquiring coal reserves.(41) The potential of supplying alternative sources of energy at lower per unit cost is also being more closely studied. The prospect of increasing earnings through future cost minimization, especially if a comparative advantage in the production of non-conventional sources of energy may be established, prompts the intensification of R & D. into energy sources. The intensity with which search activities are conducted is a function of expected returns on current investment and capital availability.

On a relatively small scale, the conversion of biomass into fuels, with the potential of yielding 10 quads(42) by the end of the century, the derivation of fuel from municipal solid wastes,(42) of methane gas generation from agricultural wastes, of plantation of energy crops and of fuller utilization of hydropower/wind potentials(43) are no longer on the drawing board only. While such economic activities can make a significant contribution to increasing energysupply at competitive prices in the short run, they still cannot adequately meet the expected increase in demand for energy sources in the long run. Corporations with capital and technical know-how are more intent upon abundant supply of energy forms at acceptable prices over the long run. Their R & D efforts are thus concentrated on exploiting the potential of near inexhaustible or inexhaustible sources.

Each research unit operates within its own financial, technological constraints and risk-taking instincts. Dow Chemical's recent success with coal liquefaction process, which not only promises the supply of oil from coal at competitive costs--between $20 to $27 per barrel--but that liquefied coal could be on the market in ten years, is but one of the many steps being taken by future energy suppliers. Gulf Oil Corp. is to spend $800 million to develop a uranium mine in New Mexico, the Minnesota Gas Company has been experimenting with peat gasification, and peat harvesting equipments are already being assembled in North Carolina. If successful, and given the estimate of peat reserve in the U. S. at 120.5 billion tons, the content of energy equivalent is 240 billion barrels of oil, rivaling the current oil reserve in Sauding Arabia.(44) Union Oil has deemed geothermal energy worth exploring and worth developing technology for to capture "steam and hot water from deep in the earth's crust to spin turbines and generate electricity."(45) So far, more than $150 million has already been invested in the venture. Though there are associated impediments in harnessing geothermal power as a source of future energy supply, the "reserve" of geothermal energy may theoretically supply increasing energy demand for millions of years.(46) Syncrude Canada Ltd. has begun exploiting the Athabasca tar sands in northern Alberta. It has developed the technical knowledge to garnish oil from tar sands "on an impressive scale."(47) Though the volume of extractable oil from tar sands is low relative to geothermal sources, it represents a potential of 600 percent of known oil reserve in the U. S.(48) Attempts at obtaining oil from shale whose existence has long been known to scientists are also underway. Worldwide estimate of recoverable oil from shale in 1965 was 190 billion barrels. By 1973, the potentially recoverable oil from shale in the Colorado, Utah and Wyoming region alone was estimated to be 2.6 trillion barrels while world wide shale oil potential is estimated by U.S. Geological Survey in 1973 to be nearly 10 times greater than that of oil, natural gas and coal combined.(49) Fusion as a source of potential energy supply has also been given increasing attention, although not as much as it deserves. For "nuclear fusion could be practically free of resource constrains, since the ^{2}H, easily extractable from sea water, represents about 500,000 times the energy content of fossil fuels."(50)

The one source of energy that environmentalists favor most is solar, the original endower of all forms of conventional energy on earth. The sun releases 100 x 10^{24} calories per second. If completely captured for use by humans, each person each second would "enjoy" 70,000 times more energy than the total annual energy consumption of the U. S. Of the total energy emitted by the sun, only 2/1 billionth reaches the outer sphere of the earth. That "little" is "equivalent in

energy to about 100 million Hiroshima-size atomic bombs per day."[51] Of the energy that does penetrate through the earth's outer atmospheric layers, only one third of 1 percent is "productively" utilized.[52] If only fifty percent of the sunshine that falls upon the 1. S. roads each year were collected and converted to usable forms, the annual energy demand for the entire world would already be met.[53] The rapid oil price increases in recent years have provided just the needed economic inducement to harness solar energy for commercial usages. Passive solar energy collection most commonly comes in the form of solar collectors on earth to be used for space heating and cooling, swimming-pool heating, cooking and other domestic usages. Between 1976 and 1977, solar collector production in the U. S. nearly tripled and, given financial incentives to manufacturers and users,[54] the U. S. administration projects "2.5 million solar homes" by 1985."[55] On the electricity supply front, solar power plants are no longer a remote possibility but are "moving from research to development, demonstration and commercialization," and are about to achieve the cost effective stages.[56] In space, Satellite Solar Power Stations based on the principle of photovoltaic conversion can provide 24-hour a day continuous "production" of energy for use. Photovoltaic cells, fashioned from silicon, can "generate electricity directly when sunlight falls on them. They have no moving parts, consume no fuel, produce no pollution, operate at environmental temperature, having long lifetimes [and] require little maintenances."[57] The solar generated electricity can then be transmitted to regional storage systems on earth via microwave beams with remarkably high efficiency and minimal loss.[58] The Council on Environmental Quality believes that the U. S. is capable of deriving 25 percent of its energy demand from the sun by 2,000 A. D., more than 50 percent by 2020 and becoming a solar society thereafter. And Congressional Office of Technology Assessment likewise envisions a competitive market for solar energy within 10 years.[59]

It is reasonable to conclude that the potential of various sources of energy other than oil and natural gas will continue to be explored and exploited. The cost of per energy unit production at a given state of the art will determine which form of the said alternative sources will increasingly substitute for the use of oil and natural gas over time. And any technological breakthrough in any of the fields will only hasten to toll the knell for oil/ gas supremacy, at least in developed economies. Future prices of oil and gas, national energy policy and the extent of financial incentives provided by the governments will significantly determine which form of energy source will be predominant in the market and will significantly affect the dawning of a new era in energy consumption. Sources of energy, whether conventional or otherwise, are more than ample in a market situation where price and profit govern the use or disuse of any resource. Although the "harm is done," the OPEC nations may well resort to "loss minimization" in the long run by stabilizing or even reducing current oil and gas prices so as to dampen the feverish market incentives currently underway in search for substitute forms of energy.

6. CONCLUSION

Societies do not survive or perish due to the abundance or shortage of one natural resource. Despite the uniquely important role played by conventional sources of energy in developed economies, human ingenuity, prodded along by economic forces, is more than capable of neutralizing the current apprehension over energy "shortage". Substitute forms of energy, more abundant and less expensive than oil and gas, will be in commercial use before long. Future increase in oil and gas prices will only hasten the arrival of such substitute energy forms. It is realistic to conclude that there will not be a permanent shortage of energy supply and that the current energy crisis will be a page of past history in the foreseeable future.

REFERENCES

(1) Boserup, Mogen, "Resources, Environment and the Rationale of Population Policy," The Population Debate: Dimensions and Perspectives, Vol. II, New York: United Nations, 1975. P. 199.

(2) Kahn, Herman, William Brown and Leon Martel, The Next 200 Years: A Scenario for America and the World, New York: William Morrow and Co., Inc. 1976. PP. 94-95.

(3) Reno, Horace T., "The Mineral Industry of the United Kingdom," Minerals Yearbook, Vol. III, (Area Reports: International), Washington, D. C.: United States Government Printing Office, 1976. P. 923.

(4) Markham, Jesse W., Anthony P. Hourihan and Francis L. Sterling, Horizontal Divestiture and the Petroleum Industry. Mass.: Ballinger Publishing Co., 1977, p. 21.

(5) Science News. Vol. 114, No. 11, Sept. 9, 1978. P. 186.

(6) Connelly, Philip and Robert Perlman, The Politics of Scarcity, New York: Oxford University Press, 1975.

(7) Cook, Earl, Man, Energy, Society, San Francisco: W. H. Freeman and Company, 1976. P. 393.

(8) Beckerman, Wilfred, Two Cheers for the Affluent Society, (A Spirited Defense of Economic Growth), New York: Saint Martin's Press, 1975. P. 208.

(9) Landsberg, Hans H., "Low Cost, Abundant Energy: Paradise Lost?" Energy: Use, Conservation and Supply, Philip H. Abelson (ed.) Washington, D. C.: American Association for the Advancement of Science, 1974. P. 4.

(10) Darmstadter, Joel and Hans H. Landsberg, "The Economic Background," The Oil Crisis: In Perspective, Daedalus, Massachusetts: American Academy of Arts and Sciences, Fall 1975. P. 30.

(11) Landsberg, op. cit.

(12) Brooks, David B. and Peter W. Andrews, "Minearl Resources, Economic Growth, and World Population," Materials: Renewable and Nonrenewable Resources, Philip H. Abelson and Allen L. Hammond (eds.) Washington, D. C. : American Association for the Advancement of Science, 1976. P. 41.

(13) Cook, op. cit. P. 393 ff.

(14) Peach, W. N., The Energy Outlook for the 1980's, Washington, D. C. : United States Government Printing Office, 1973. P. 3.

(15) Ibid.

(16) Tuve, George L., Energy, Environment, Populations and Food, John Wiley & Sons, Inc., 1976. P. 226.

(17) Peach, op. cit. P. 3.

(18) Darmstadter, op. cit. P. 158.

(19) Greenblat, Edward, "Space-Based Solar Power Conversion and Delivery Systems Study," Solar Power from Satellites, Washington, D. C. : U. S. Government Printing Office, 1976. P. 155.

(20) Jacoby, Neil H., Multinational Oil, New York: MacMillan Publishing Co., Inc., 1974. P. 248.

(21) Ibid., p. 236.

(22) Ibid. P. 68.

(23) Ibid. P. 250.

(24) Ridker, Ronald G., "Natural Resource Adequacy and Alternative Demographic Prospects," United Nations, The Population Debate: Dimensions and Perspectives, op. cit. P. 37.

(25) Hayes, Denis, Rays of Hope: The Transition to a Post Petroleum World, New York: W. W. Norton & Co. Inc., 1977. PP. 142-143.

(26) Beckerman, op. cit. P. 209.

(27) Ibid. P. 208.

(28) Brubaker, Sterling, In Command of Tomorrow: Resource and Environmental Strategies for Americans, Baltimore: Johns Hopkins University Press, 1975. P. 61.

(29) Brooks and Andrews, op. cit. P. 41.

(30) Gonzalez, Richard J, "The Possible Impact of Environmental Standards on the Availability and Cost of Petroleum," Energy, Economic Growth and the Environment, Sam H. Schurr (ed.) Baltimore: Johns Hopkins University Press, 1972. P. 95.

(31) Peach, op. cit. P. 6.

(32) Darmstadter and Landsberg, op. cit. P. 30.

(33) Maddox, John, The Doomsday Syndrome, New York: McGraw-Hill Book Company, 1972. P. 152; Tuve, op. cit., p. 227; and, Markham et alii, op. cit. P. 21.

(34) Scherer, F. M., Industrial Market structure and and Economic Performance, Chicago: Rand McNally College Publishing Company, 1970. P. 215.

(35) Brooks and Adrews, op. cit. P. 43.

(36) Abelson, Philip H., "Five Years of Energy Paralysis," Science, Vol. 201, #4358, 1 September, 1978. P. 775.

(37) "New World Economic Order," BusinessWeek, July 24, 1978. P. 71.

(38) "Dry Holes and Discoveries," Time, July 24, 1978. P. 52.

(39) "The Gas Hoarders May Lose a Price Bet," BusinessWeek, May 29, 1978. P. 29.

(40) Barry, John, "Whatever Happened to that Shortage of Natural Gas?" Forbes, September 4, 1978. P. 32.

(41) "The Anatomy of U. S. Industry's Investment Dilemma," BusinessWeek, October 17, 1978. P.110.

(42) "Photosynthetic Solar Energy: Rediscovery Biomass Fuels," Science, Vol. 197, No. 4305, 19 August, 1977. P. 745.

(43) "Energy: Elements of a Latin American Strategy," Science, Vol. 200, 19 May 1978. P. 753.

(44) "Peat for Fuel: Development Pushed by Big Corporate Firm in Carolina," Science, Vol. 199, Jan. 6, 1978. PP. 33-34; and, "The New Diversification Oil Game," BusinessWeek, April 24, 1978. P.79.

(45) "Union Oil Gets up Steam for Geothermal Energy," Fortune, July 31, 1978. P. 94 ff.

(46) Kahn et alii, op. cit.PP. 63, 74; Rocks,Lawrence and Richard P. Runyon, The Energy Crisis: The Imminent Crisis of Our Oil, Gas, Coal and Atomic Energy Resources and Solutions to Resolve It. Crown Publications, 1972. P. 57.; and, George Tyler Miller, Replenish the Earth, Calif.Balmount: Wadsworth Publishing Co., 1972. P. 130.

(47) "Canada Goes after Energy in the Tar Sands," Fortune, May 22, 1978. P. 72 ff.

(48) Kahn et. alii, op. cit. P. 63.

(49) National Academy of Sciences, Committee on Resources and Man, Resources and Man, San Francisco: W. H. Freeman & Co., 1969. P. 200.

(50) Thom, W. Taylor Jr., "The Discovery, Development and Constructive Use of World Resources," in The Population Crisis and the Use of World Resources, Stuart Mudd (ed), Bloomington: Indiana University Press, 1964, PP. 493-494; and, Amory B. Lovings, "Energy Resources," in The Population Debate: Dimensions and Perspectives Vol. II., op. cit. P. 56.

(51) Miller, op. cit. PP. 57-58.

(52) Ward, Barbar, and Rene Dubos, Only One Earth. New York: W. W. Norton & Co., 1972. P. 128.

(53) Hayes, op. cit. P. 156.

(54) The National Energy Plan. Executive Office of the President, Energy Policy and Planning, Washington, D. C., 1977 P. 75.

(55) "Energy," Science News, Vol. 114, No. 2, July 8, 1978. P. 28.

(56) Murphy, Lawrence M. and Alan C. Skinrood, "Coming: Solar Power Plants," Mechanical Engineering, November 1976. P. 26 ff.

(57) Hayes, op. cit. PP. 166-167.

(58) Solar Power from Satellites, Hearings before the Subcommittee on Aerospace Technology and National Needs, 94th Congress, Washington, D. C.: Government Printing Office, 1976. Stock No. 052-070-033193. P. 20 ff.

(59) "A Bright Solar Prospect Seen by CEQ and OTA," Science, Vol. 200, 12 May 1978. P. 627 ff.